Structure Force Analysis for Reinforced Concrete Bifurcation Pipe of Dongjiang Hydropower Station

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Abstract—Bifurcated pipe belongs to complex spatial structure, and when it bears the inner and the external water pressure, the bifurcation structure enters in complex stress state. Dongjiang Hydropower Station is located upstream of the Xiangjiang River tributary in the southeastern territory of Zixing, Hunan province and it is a large hydropower projects with comprehensive benefits such as a power generation, flood control, navigation, and industrial and agricultural water using and so on. In this paper, using the finite element method of reinforced concrete bifurcation structure of Dongjiang hydropower station analyzes the stress so that the analysis results play a vital role in providing strong theoretical evidence for the operation if it is safe. The results prove that the surrounding rock are binding on the bifurcation pipe so that fork tubes can significantly reduce stress and have a positive impact on the safety for the bifurcation pipe.

Keywords-Dongjiang hydropower; Reinforced concrete bifurcation pipe; Surrounding rocks; Stress distribution; Finite element method.

I. ENGINEERING SITUATION

Dongjiang Hydropower Station is located upstream of the Xiangjiang River tributary in the southeastern territory of Zixing, Hunan province and it is a large hydropower projects with comprehensive benefits such as a power generation, flood control, navigation, and industrial and agricultural water using and so on. The total installed capacity of Dongjiang hydropower is 510MW, arranging in the form of a water diversion system with 3-hole machine. Diversion system makes up with the library into (out of) the outlet,a water main tunnel,upstream surge chamber, pressure tunnel,asymmetric Y-shaped bifurcation pipe and the three high-pressure branch pipes that the water main tunnel's diameter is 11.00m and branch tunnel's diameter is 5.40m and the non-symmetrical Y-shaped bifurcation pipe's angle which is the angle between of two holes is 60°. During the operation the bifurcated pipes' maximum hydrostatic pressure is 1.874 MPa[1] .The maximum water hammer pressure is 0.36 MPa and the backfilled grouting pressure is 0.3 MPa. Director of lining concrete thickness is 0.8 m and bifurcated pipes'

lining concrete thickness is 1.2 m with the branch pipe lining thickness of 0.6 m and lining concrete strength class C25. The location of bifurcation pipes where the actual wall rock overburden thickness is 260 m[2].

II. CALCULATION MODEL

A Model Parameters

The reinforce concrete bifurcation pipe of Dongjiang hydropower station uses the concrete strength class C15,elastic modulus $E_1 = 28$ GPa, poisson's ratio $\mu_1 = 0.167$ [3-4], bulk density $\gamma_1 = 24 \, \text{kN/m}^3$.
Selecting the 40 mm thick high-strength steel liner plate whose elastic modulus $E_2 = 210$ GPa, Poisson's ratio $\mu_2 = 0.28$,bulk density $\gamma_1 = 78.5 \, \text{kN/m}^3$.Surrounding rocks classification belonging bifurcation pipes is C Ⅱ .Surrounding rocks' material handling makes the isotropic, linear elastic whose elastic modulus is $E_2 = 20$ GPa, poisson's ratio $\mu_2 = 0.21$ [5-6],bulk density

$$\gamma_1 = 28 \, \text{kN/m}^3.$$

B Model Element

Concrete pipes and surrounding rocks use an 8-node isoparametric block element and steel liners with a 4-node shell element[7-8].The total number of computational models are 29,821 nodes as with the total number of elements is 45,913, of which, SOLID45 number of cells surrounding rock is 22404 and SOLID45 of bifurcation pipes' number of elements is 22847 and SHELL63 of steel liners' number of elements is 662[9].

C Finite Element Model

When using the finite element method for the bifurcation structure makes the finite element analysis , we must firstly establish a finite element model of bifurcation structure, as shown the finite element partition in bifurcated pipes and surrounding rock structures in Fig .1, Fig .2.
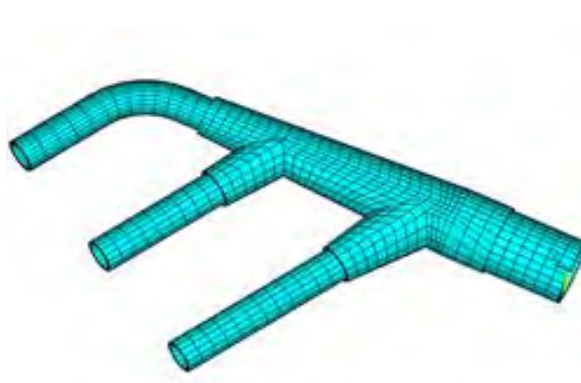
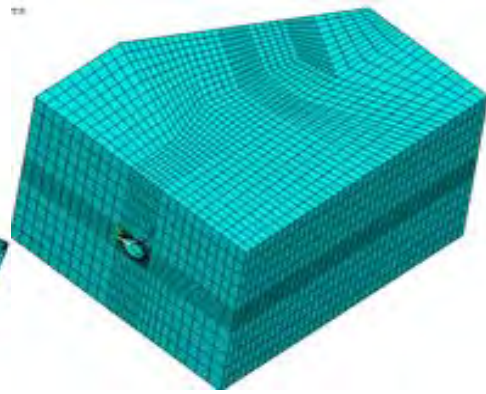Figure 1. The finite element model of the bifurcation pipe

Figure 2. The finite element model of the surrounding rock

D Calculation Condition

According to the mechanical characteristics of concrete bifurcation of the Dongjiang Hydropower Station to run[10], the main consideration of the following four kinds of calculation condition: Case 1,the internal water pressure (internal water pressure is 2.234 MPa), case 2,the internal water pressure (internal water pressure 2.234 MPa and rock constraint), case 3,the internal water pressure (internal water pressure 2.234 MPa, rock constraint and rock weight),case 4,the internal water pressure (internal water pressure 2.234

MPa and external pressure (grouting pressure 0.3 MPa and rock constraints).

III. STRUCTURE ANALYSIS

A Stress Analysis

Under each condition the bifurcation structure of the first principal stress cloud can be seen from the Fig .3 to Fig .6. In the case 2 and case 3 the bifurcated pipe of the first principal stress cloud with surrounding rock can be seen from the Fig .7 to Fig .8.
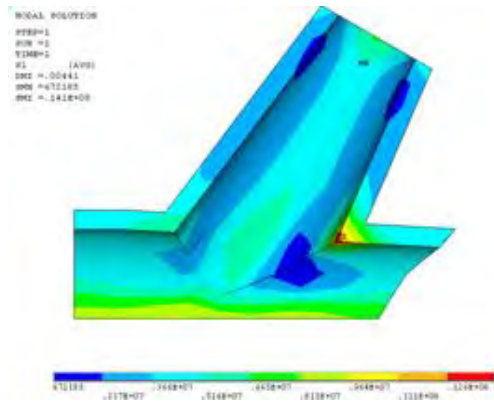

Figure 3. Case 1 the bifurcated pipe of the first principal stress cloud(Pa)
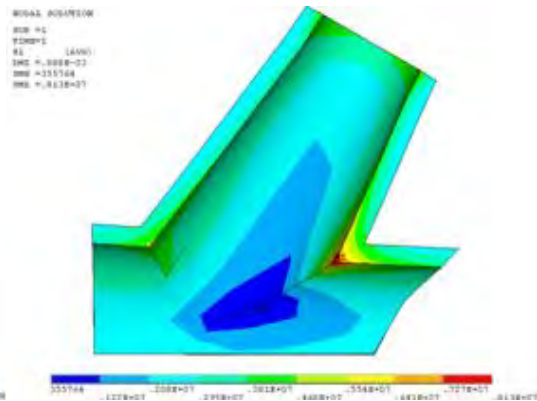

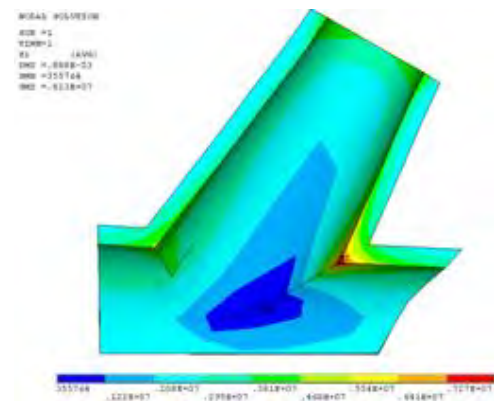Figure 4. Case 2 the bifurcated pipe of the first principal stress cloud(Pa)

Figure 5. Case 3 the bifurcated pipe of the first principal stress cloud(Pa)
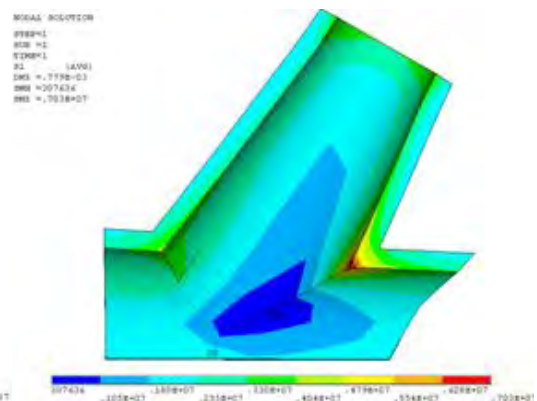

Figure 6. Case 4 the bifurcated pipe of the first principal stress cloud(Pa)
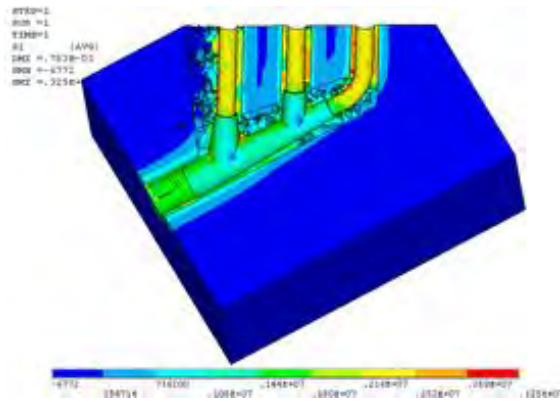
Figure 7. Case 2 the surrounding rock of the first principal stress cloud(Pa)
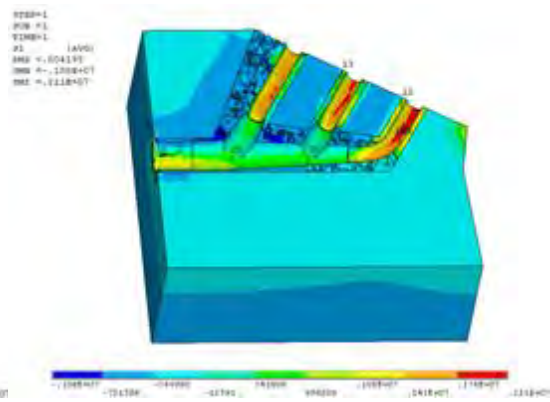

Figure 8. Case 3 the surrounding rock of the first principal stress cloud(Pa)

As we can see from the Fig .3 to Fig .6, under the internal water pressure, the maximum principal stress of bifurcated pipe first majorly appears at the intersecting lines in the fork tube surface, and with the weakening of the bifurcation pipe's periphery constraint,the biggest first main constraint stress increases. This is the mainly reason from the presence of sharp corners here, under the load,where has been more serious concentration about the stress.

From the Fig .7 to Fig .8, we can see the maximum first principal stress were 3.25MPa and 2.11MPa in cases 2 and 3 under the surrounding rock of bifurcation pipes with the maximum principal stress mainly occurring in the sharp parts of the bifurcation.Since the bifurcation pipe has many forks so

that we only select the competent local coordinate system to analyze the surrounding rock's circumferential stress.The surrounding rock's circumferential stress also appears in the sharp parts of the bifurcation, most of the remaining circumferential stress less than 1 MPa.If taking into account the plastic deformation of surrounding rock and redistribution of internal forces, the rock in the construction and operation phase is security.

B   Deformation Analysis

In order to study the deformation analysis of bifurcation structures, the main consideration is analyzed sections shown in Fig .9.
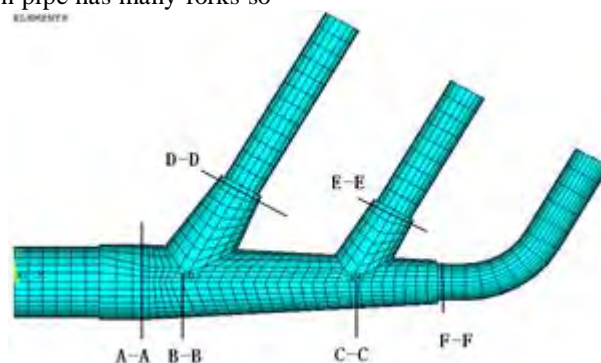

Figure 9. The bifurcated pipe deformation analysis of cross-sectional schematic

In all four cases, the case 1 is an unlikely extreme conditions, so the bifurcation structure deformation analysis only calculates the remaining three conditions. By calculation gives the three results about the deformed

state of each section on conditions in the calculated point calculations of six months.Now putting three conditions of the maximum radial internal and external displacement values is listed in Table 1

TABLE 1. THREE CASES OF EXTREME DISPLACEMENT CONDITIONS

condition	The maximum radial internal displacement（months）	The maximum radial external displacement（months）
Case 2	no	0.827（B-B month）
Case 3	4.31（A-A month）	4.16（D-D month）
Case 4	no	0.703（B-B month）

In case 2 and 4, the structure of the radial displacements are within 1 mm, which will not cause a great impact on the normal using structure. In case 3 the structure has the larger radial displacement, which is mainly due to take into account the weight of the mountain leading to the displacement.but in fact before the construction the settlement from the weight of the mountain has been and carried out when we calculate the deformation which don't belong the settlement.

IV. CONCLUDING REMARKS

In summary, the reinforced concrete of Dongjiang Hydropower is designed reasonably, the larger stress from the bifurcation pipe's branch.And by the strength the number of the reinforcement to meet the conditions.The rock stress value is smaller so it can not crack. Deformation value is smaller of the bifurcation pipe to meet stiffness criteria.

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